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APPLICATION FOR UNITED STATES LETTERS PATENT

FOR

RADIALLY ADJUSTABLE DOWNHOLE DEVICES & METHODS FOR SAME

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CROSS-REFERENCE TO RELATED APPLICATIONS

This application Claims the benefit of earlier filed provisional United States Patent Application Serial No. 60/448,388, filed on Feb. 18, 2003.

Field of the Invention

This invention relates generally to oilfield wellbore tools and more particularly to well logging devices that have radially adjustable modules.

Background of the Art

Oil or gas wells are often surveyed to determine one or more geological, petrophysical, geophysical, and well production properties ("parameters of interest") using electronic measuring instruments conveyed into the wellbore by an umbilical such as a cable, a wireline, slickline, drill pipe or coiled tubing. Tools adapted to perform such surveys are commonly referred to as formation evaluation tools. These tools use electrical, acoustical, nuclear and/or magnetic energy to stimulate the formations and fluids within the wellbore and measure the response of the formations and fluids. The measurements made by downhole instruments are transmitted back to the surface. In many instances, multiple trips or logging runs are needed to collect the necessary data.

As is known to those versed in the art, certain tools collect a first set of data while in a substantially concentric position relative to the wellbore and collect a second set of data while in a substantial eccentric position relative to the wellbore. Conventionally, the position of tools on an umbilical are static or fixed. Thus, two or more logging runs may be required to collect the two types of data, even though one tool can collect both types of data. As is also known in the art, certain logging runs can utilize a dozen or more different measurement tools in a single package. Each of these tools may require a different position relative to the wellbore (*e.g.*, radial position relative to the wellbore axis) and/or different physical orientation relative to one another.

Merely by way of illustration and not to limit the scope and application of the present invention, reference is made to a nuclear magnetic resonance ("NMR") tool such as that described in U.S. Patent Application Ser. No. 09/997,451 ("'451 Application") having the same assignee as the present application and the contents of which are fully incorporated herein by reference. The '451 Application describes an NMR tool that may be operated in a centralized position in a small diameter borehole and in a decentralized position in a large diameter borehole. The NMR tool is merely representative of a number multi-purpose tools that, conventionally, are re-set in different radial positions (*e.g.*, alignment, orientation, etc.) at the surface in order to perform different tasks downhole (*e.g.*, collect different types of data).

The present invention addresses these and other drawbacks of conventional well tools.

SUMMARY OF THE INVENTION

The present invention provides a tool system having at least one module that can be placed in a selected position relative to a reference object. The selected position can be a radial position relative to a wellbore axis or a selected orientation (*e.g.*, azimuth, inclination) relative to an adjacent module. The tool system is adapted to be deployed at a rig that is positioned over a subterranean formation of interest. In one embodiment, the tool system is conveyed downhole via a wireline into a wellbore and includes one or more modules housing a measurement device adapted to measure a parameter of interest. In one embodiment, the module carrying the measurement device is provided with a positioning device. The positioning device is configured to adjust and/or maintain an associated module at a selected radial position relative to a reference point or object (*e.g.*, wellbore axis or proximally positioned downhole device). The positioning device adjusts *in situ* the radial position of module upon receiving a command signal and/or automatically in a closed-loop type manner. This selected radial position is maintained or adjusted independently of the radial position(s) of an adjacent module or modules. An exemplary positioning device includes a plurality of independently adjustable positioning members and

associated drive assemblies. The drive assemblies and the positioning members are configured to provide fixed or adjustable radial displacement and/or fixed or adjustable amount of force against the wellbore wall. The tool system communicates with surface equipment (e.g., a controller) via telemetry equipment that provides two-way exchanging data/command signals.

In another embodiment of the present invention, the positioning device is adapted to provide a selected orientation for a module relative to an adjacent module. For instance, the positioning device can include a swivel driven by a suitable mechanism that orients a first module at a selected inclination relative to a second module. The swivel can also be configured to set the first module at a selected azimuth relative to a second module or set both a relative azimuth and inclination. In still another embodiment of the present invention, the positioning device is adapted to provide a jarring force. For instance, the positioning members of the positioning device are adapted to jar a device such as a formation-sampling tool free by inducing a steady or pulsed radial force against the wellbore wall.

In one manner of operation involving an acoustic tool, the acoustic tool is conveyed into the wellbore by a tool module until the acoustic tool is positioned adjacent an open hole section. If needed, the acoustic tool is set in a centralized position relative to the wellbore axis for acoustic logging. After acoustic logging is complete, actuation of one or more positioning devices places the acoustic tool in a substantially eccentric or decentralized radial position relative to the wellbore. This decentralized position can, for instance, acoustically couple the acoustic tool to the wellbore wall and enable check-shot measurements. During the data collection, the controllers can be configured to analyze the measurement by, for example, comparing the data to a pre-determined model. After completion of acoustic logging and taking of check-shot data measurements (on the same logging run), the tool can be positioned in the cased region of the wellbore. In this position, the positioning devices set the acoustic tool in a substantially concentric position for to collected different data, *e.g.*, data relating to the bonding of the cement to the casing.

Examples of the more important features of the invention have been summarized (albeit rather broadly) in order that the detailed description thereof that follows may be better understood and in order that the contributions they represent to the art may be appreciated. There are, of course, additional features of the invention that will be described hereinafter and which will form the subject of the claims appended hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

For detailed understanding of the present invention, reference should be made to the following detailed description of the preferred embodiment, taken in conjunction with the accompanying drawing:

Figure 1 is a schematic illustration of one embodiment of a system using a radially adjustable module adapted for use in logging operations;

Figure 2 illustrates a sectional view of one embodiment of a positioning device made in accordance with the present invention;

Figure 3A is a schematic elevation view of radially adjustable module positioned in an open hole portion of a wellbore;

Figure 3B is a schematic elevation view of radially adjustable module positioned in a cased portion of a wellbore;

Figure 3C is a schematic elevation view of a module provided with an embodiment of a jarring device made in accordance with the present invention;

Figure 3D is a schematic elevation view of an alternate embodiment of a positioning member;

Figure 3E is a schematic elevation view of yet an alternate embodiment of a positioning member; and

Figure 4 schematically illustrates one embodiment of an arrangement according to the present invention wherein a positioning tool is configured to adjust the radial position of a measurement device.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring initially to Figure **1**, there is shown a rig **10** on the surface that is positioned over a subterranean formation of interest **12**. The rig **10** can be a part of a land or offshore a well production/construction facility. A wellbore **14** formed below the rig **10** includes a cased portion **16** and an open hole portion **18**. In certain instances (*e.g.*, during drilling, completion, work-over, etc.), a logging operation is conducted to collect information relating to the formation **12** and the wellbore **14**. Typically, a tool system **100** is conveyed downhole via an umbilical **110** to measure one or more parameters of interest relating to the wellbore **14** and/or the formation **12**. The term "umbilical" as used hereinafter includes a cable, a wireline, slickline, drill pipe, coiled tubing and other devices suitable for conveying a tool into a wellbore. The tool system **100** can include one or more modules **102 a,b**, each of which has a tool or a plurality of tools **104 a,b**, adapted to perform one or more downhole tasks. The term "module" should be understood to be a device such as a sonde or sub that is suited to enclose, house, or otherwise support a device that is to be deployed into a wellbore. While two proximally positioned modules **102 a,b** and two associated tools **104 a,b,** are shown, it should be understood that a greater or fewer number may be used.

In one embodiment, the tool **104a** is formation evaluation tool adapted to measure one or more parameters of interest relating to the formation or wellbore. It should be understood that the term formation evaluation tool encompasses measurement devices, sensors, and other like devices that, actively or passively, collect data about the various characteristics of the formation, directional sensors for providing information about the tool orientation and direction of movement, formation testing sensors for providing information about the characteristics of the reservoir fluid and for evaluating the reservoir conditions. The formation evaluation sensors may include resistivity sensors for determining the formation resistivity, dielectric constant and the presence or absence of hydrocarbons, acoustic sensors for determining the acoustic porosity of the formation and the bed boundary in formation, nuclear sensors for determining the formation

density, nuclear porosity and certain rock characteristics, nuclear magnetic resonance sensors for determining the porosity and other petrophysical characteristics of the formation. The direction and position sensors preferably include a combination of one or more accelerometers and one or more gyroscopes or magnetometers. The accelerometers preferably provide measurements along three axes. The formation testing sensors collect formation fluid samples and determine the properties of the formation fluid, which include physical properties and chemical properties. Pressure measurements of the formation provide information about the reservoir characteristics.

In certain embodiments, the tool system **100** can include telemetry equipment **150**, a local or downhole controller **152** and a downhole power supply **154**. The telemetry equipment **150** provides two-way communication for exchanging data signals between a surface controller **112** and the tool system **100** as well as for transmitting control signals from the surface processor **112** to the tool system **100**.

In an exemplary arrangement, and not by way of limitation, a first module **102a** includes a tool **104a** configured to measure a first parameter of interest and a second module **102b** includes a tool **104b** that is configured to measure a second parameter of interest that is either the same as or different from the first parameter of interest. In order to execute their assigned tasks, tools **104a** and **104b** may need to be in different positions. The positions can be with reference to an object such as a wellbore, wellbore wall, and/or other proximally positioned tooling. Also, the term "position" is meant to encompass a radial position, inclination, and azimuthal orientation. Merely for convenience, the longitudinal axis of the wellbore ("wellbore axis") will be used as a reference axis to describe the relative radial positioning of the tools **104a,b**. Other objects or points can also be used as a reference frame against which movement or position can be described. Moreover, in certain instances, the tasks of the tools **104a,b** can change during a wellbore-related operation. Generally speaking, tool **104a** can be adapted to execute a selected task based on one or more selected factors.

These factors can include, but not limited to, depth, time, changes in formation characteristics, and the changes in tasks of other tools.

In accordance with one embodiment of the present invention, modules **102a** and **102b** are each provided with positioning devices **140a**, **140b,** respectively. The positioning device **140** is configured to maintain a module **102** at a selected radial position relative to a reference position (e.g., wellbore axis). The position device **140** also adjusts the radial position of module **102** upon receiving a surface command signal and/or automatically in a closed-loop type manner. This selected radial position is maintained or adjusted independently of the radial position(s) of an adjacent downhole device (e.g., measurement tools, sonde, module, sub, or other like equipment). An articulated member, such a flexible joint **156** which couples the module **102** to the tool system **100** provides a degree of bending or pivoting to accommodate the radial positioning differences between adjacent modules and/or other equipment (for example a processor sonde or other equipment). In other embodiments, one or more of the positioning devices has fixed positioning members.

According to one embodiment, the positioning device **140** includes a body **142** having a plurality of positioning members **144** **(a,b,c)** circumferentially disposed in a space-apart relation around the body **142**. The members **144** **(a,b,c)** are adapted to independently move between an extended position and a retracted position. The extended position can be either a fixed distance or an adjustable distance. Suitable positioning members **144** **(a,b,c)** include ribs, pads, pistons, cams, inflatable bladders or other devices adapted to engage a surface such as a wellbore wall or casing interior. In certain embodiments, the positioning members **144** **(a,b,c)** can be configured to temporarily lock or anchor the tool in a fixed position relative to the wellbore and/or allow the tool to move along the wellbore.

Drive assemblies **146** **(a,b,c)** are used to move the members **144** **(a,b,c)**. Exemplary embodiments of drive assemblies **146** **(a,b,c)** include an electro-mechanical system (*e.g.*, an electric motor coupled to a mechanical linkage), a hydraulically-driven system (*e.g.*, a piston-cylinder arrangement fed with

pressurized fluid), or other suitable system for moving the members **144 (a,b,c)** between the extended and retracted positions. The drive assemblies **146 (a,b,c)** and the members **144 (a,b,c)** can be configured to provide a fixed or adjustable amount of force against the wellbore wall. For instance, in a positioning mode, actuation of the drive assemblies **146 (a,b,c)** can position the tool in a selected radial alignment or position. The force applied to the wellbore wall, however, is not so great as to prevent the tool from being moved along the wellbore. In a locking mode, actuation of the drive assembly **146 (a,b,c)** can produce a sufficiently high frictional force between the members **144 (a,b,c)** and the wellbore wall as to prevent substantial relative movement. In certain embodiments, a biasing member (not shown) can be used to maintain the positioning members **144 (a,b,c)** in a pre-determined reference position. In one exemplary configuration, the biasing member (not shown) maintains the positioning member **144 (a,b,c)** in the extended position, which would provide centralized positioning for the module. In this configuration, energizing the drive assembly overcomes the biasing force of the biasing member and moves one or more of the positioning members into a specified radial position, which would provide decentralized positioning for the module. In another exemplary configuration, the biasing member can maintain the positioning members in a retracted state within the housing of the positioning device. It will be seen that such an arrangement will reduce the cross sectional profile of the module and, for example, lower the risk that the module gets stuck in a restriction in the wellbore.

The positioning device **140** and drive assembly **146 (a,b,c)** can be energized by a downhole power supply (*e.g.*, a battery or closed-loop hydraulic fluid supply) or a surface power source that transmits an energy stream (e.g., electricity or pressurized fluid) via a suitable conduit, such as the umbilical **120**. Further, while one drive assembly (*e.g.*, drive assembly **146 a**) is shown paired with one positioning member **144** (*e.g.*, position member **144 a**), other embodiments can use one drive assembly to move two or more positioning members.

Referring now to **Figur s 3A** and **3B** there is shown an exemplary formation evaluation tool system **200** disposed in an open hole section **18** and cased section **16** of a well, respectively. The tool system **200** includes a plurality of modules or subs for measuring parameters of interest. An exemplary module **202** is shown coupled to an upper tool section **204** and a lower tool section **206** by a flexible member **156**. In one exemplary embodiment, the module **202** supports an acoustic tool **208**. When in the open hole **18**, the acoustic tool **208** may be set in a decentralized position (*i.e.*, radially eccentric position) by actuating the positioning members **140a** and **140b**. This decentralized or radially offset position is substantially independent of the radial positions of the downhole device (e.g., measurement devices and sensors) along or in the upper/lower tool string section **204** and **206**. That is, the upper or tool string section **204** and **206** can have formation evaluation sensors and measurement devices that are in a radial position that is different from that of the module **202**. In this decentralized or radially offset position, the acoustic tool can be used to gather data such as checkshot data. In certain instances, it may be advantageous to move the module **202** in a planetary fashion along the wellbore wall. It should be appreciated that such motion can be accomplished by sequentially varying the distance of extension/retraction of the positioning members.

In **Figure 3B**, the acoustic tool **202** is shown in the cased section **16** of the wellbore **14**. In this cased section **16**, the positioning members **140a,b** are energized to bring the acoustic tool **208** into a centralized position or concentric position relative to the wellbore **14**. In this position or alignment, the acoustic tool can be configured to measure or evaluate the bond between the casing **16A** and the cement **16B**. This re-alignment of the positioning members **140a,b** can be initiated by either a locally generated command signal or a surface transmitted command signal.

Referring now to **Figure 3C**, in another embodiment of the present invention, the tool **300** can include a fluid sampling tool **302** for collecting and testing formation fluids. Conventionally, such tools include a sampling tube **304** that engages the wellbore wall **15** and, by inducing a vacuum or negative

pressure, draws wellbore fluids into sampling chambers (not shown). In certain situations, after the sampling is complete, a residual vacuum pressure remaining in the tube **304** prevents the tool **302** from dislodging from the wellbore wall **15**. Conventionally, efforts to free the tool **300** involve changing the tension force applied to the umbilical **306** on which the tool **300** is suspended. In accordance with one embodiment of the present invention, the tool includes the positioning members **308a,b** that, when energized, jars the formation-sampling tool free by inducing a steady or pulsed radial force **F** against the wellbore wall **15**.

Referring now to **Figure 3D**, there is shown an alternate embodiment of a positioning device **320** that uses an extending member **322** to selectively flex a flexible member **324** such as a bow spring. The flexible member **324** provides an arcuate surface that can be dragged along a wellbore wall **326** with reduced risk of damage and/or getting stuck in the wellbore **328**. Referring now to **Figure 3E**, there is shown a positioning device **330** that provides a module **332** with an orientation relative to another module such as adjacent module **334**. In the **Figure 3E** embodiment, the position of the module **332** is adjusted without engaging a wellbore wall (not shown). Rather, in one embodiment, a drive mechanism **338** actuates a coupling joint **340**. The coupling joint **340** is adapted to provide one or more degrees of articulation between a first module **332** and a second module **334**. Exemplary relative motion includes relative translational motion, relative rotational motion, and azimuthal rotation between the first and second modules **332, 334**. Thus, the coupling joint **340** allows the first and second modules **332, 334** to have different radial locations (*e.g.,* non-concentric tool or longitudinal center lines), different inclinations, and point in different azimuthal directions. Suitable drive mechanisms include, but not limited to, electric and hydraulic motors and hydraulic pistons energized by a pressurized fluid (*e.g.*, gas or oil). The coupling joint **340** can include a swivel arrangement and other suitable articulated members.

Referring now to **Figure 4** there is a schematically illustrated an embodiment of the present invention configured to measure formation data during a logging operation. A tool system **400** conveyed via a wireline (not

shown) includes one or more formation evaluation tools **402a**, **402b**, etc. Each tool **402a**, **402b** includes an associated positioning device **404a**, **404b**. In one embodiment, a controller **406** is configured to operate the positioning devices **404a,b** to thereby control the radial positioning of the tools **402a**, **402b**. The controller **406** preferably contains one or more microprocessors or micro-controllers for processing signals and data and for performing control functions, solid state memory units for storing programmed instructions, models (which may be interactive models) and data, and other necessary control circuits. The microprocessors control the operations of the various sensors, provide communication among the downhole sensors and provide two-way data and signal communication between the tool system **400** and the surface controller **410** via two-way telemetry system **408**.

For convenience, a single controller **406** is shown. It should be understood, however, that a plurality of controllers can also be used. For example, a downhole controller can be used to collect, process and transmit data to a surface controller, which further processes the data and transmits appropriate control signals downhole. Other variations for dividing data processing tasks and generating control signals can also be used. The controller can, thus, operate autonomously (e.g., semi-closed loop or closed-loop operation) or interactively. In certain embodiments, the controller can re-align the positioning members upon receiving surface instructions and/or re-align the positioning members using pre-programmed data (*e.g.*, well profile data such as depth). Dynamic radial position can also, in certain instances, be used to optimize the collection of data by, for example, adjusting the position of the measurement devices **402a,b** to correct for factors that influence the data measurements. Further, the controller **406** can utilize a static or dynamically-updated model to evaluate the quality of data collected by the measurement devices **402a,b** and issue command signals that re-align the positioning members to correct or optimize the data measurements. The controller **406** can also be configured to collect data from other downhole devices (e.g., sensors and measurement devices). The data from these other evaluation tools **412** (e.g.,

azimuth, tool face orientation, inclination) can also be to correct and/or optimize the data measurement process.

Referring now to **Figures 3A,B**, in one manner of operation, the tool package **100** is conveyed into the wellbore **14**, until the tool package is positioned adjacent an open hole section **18**. The wellbore **12** can include vertical sections, inclined sections or deviated sections and any horizontal portions. In one embodiment, the measurement device **208** is configured as an acoustic tool. For acoustic logging, the measurement device **208** is set in a centralized position relative to the wellbore axis. After acoustic logging is complete, the surface controller **112** and/or the downhole controller **207** actuate one or more positioning devices **204a,b** to place the tool **208** in a substantially eccentric or decentralized radial position relative to the wellbore **14**. This decentralized position can place the acoustic tool in physical contact with the wall of the wellbore **14.** This physical contact provides acoustical coupling that enables the collection of check-shot measurements. During the data collection, the controllers **112,207** can be configured to analyze the measurement by, for example, comparing the data to a pre-determined model. Based on this comparison, the controllers **112,207** can issue command signals as needed to adjust the radial position of the tool **208** to improve the quality of the measured data. Thus, for example, the controller can compensate for tool orientation in deviated portions of the wellbore by adjusting the positioning tool to maintain the tool within the selected eccentric radial position. After completion of acoustic logging and taking of check-shot data measurements (on the same logging run), the tool **208** can be positioned in the cased region **16** of the wellbore. In this position, the controllers **112,207** can operate the positioning devices **140a,b** to align the acoustic tool **208** in a substantially concentric position for to collected different data, e.g., data relating to the bonding of the cement to the casing. It should be appreciated that the controller **112,207** can work independently or in cooperation with the surface processor or surface personnel **412**. Moreover, the positioning members can be, in certain embodiments, controlled directly from the surface without use of a downhole controller.

It should therefore be appreciated that a module made in accordance with certain embodiments of the present invention can, during a single logging run, position a measurement device in a first radial position to measure a first parameter of interest, then position the measurement device in a second radial position to measure a second parameter of interest, etc. More generally, the present inventors, in certain embodiments, discloses a downhole tool that be selectively positioned to enable the execution of different downhole tasks that may be related or unrelated.

While the foregoing disclosure is directed to the preferred embodiments of the invention, various modifications will be apparent to those skilled in the art. For example, a wireline is merely one suitable conveyance mechanism. Other suitable devices include slickline, coiled tubing (metal or composite), and drill string. It is intended that all variations within the scope and spirit of the appended claims be embraced by the foregoing disclosure.